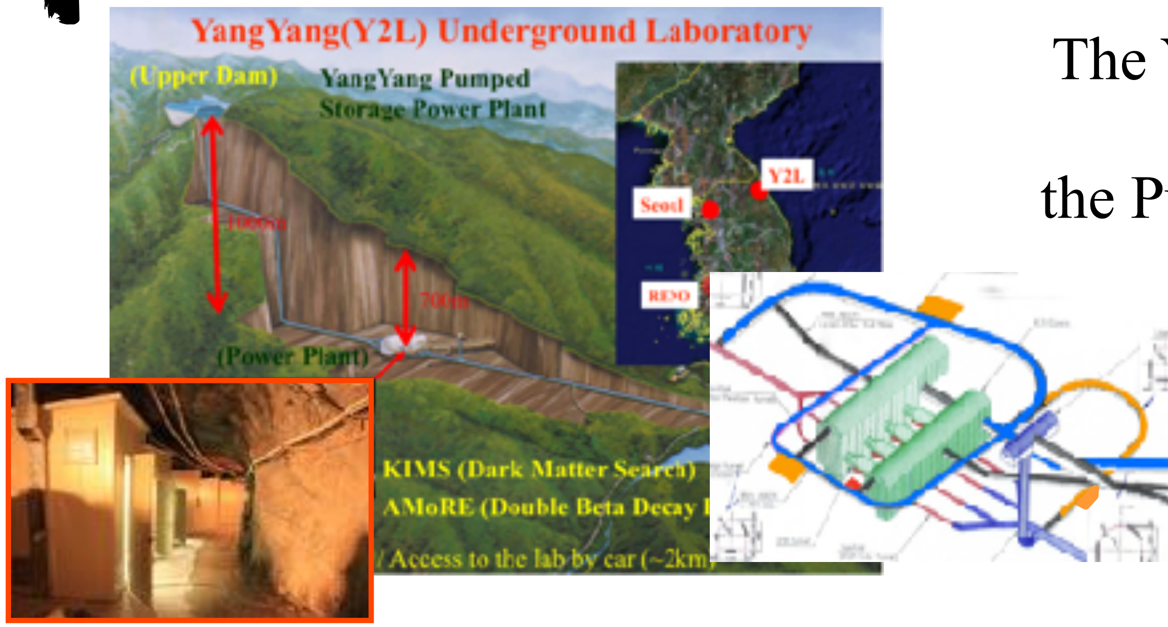
Development and Implementation of an ultra low background Array of HPGe detectors

LRT 2017

Elena Sala

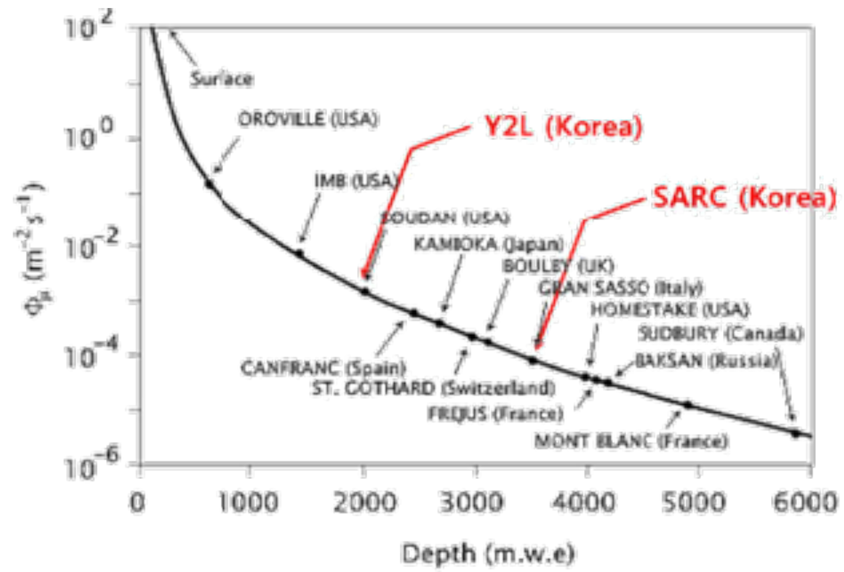
Y2L



The YangYang underground laboratory
exploits the tunnel of
the Pumped Storage Power Plant facility

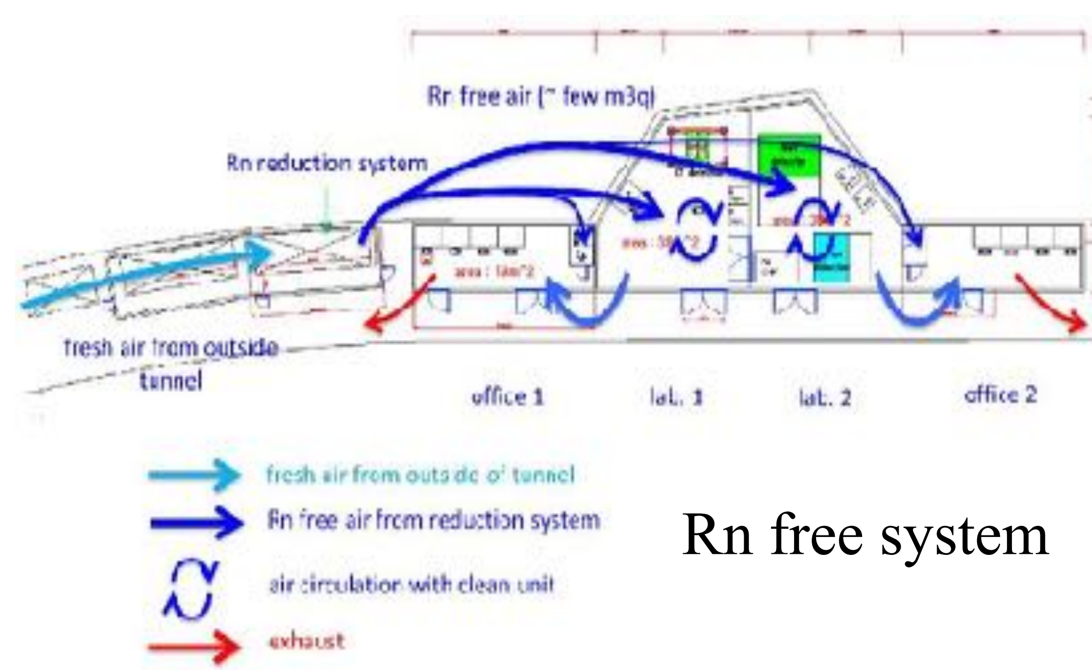
AMoRE
KIMS
HPGe Lab

700m of coverage
2000 mwe



Two main tunnels: A5 & A6
A5 hosts AMoRE, KIMS and HPGe ARRAY
A6 has R&D CsI crystals and HPGe Laboratory

HPGe detectors facility:
Low Background measurements using HPGe detectors
Material screening and selection for all the CUP experiments



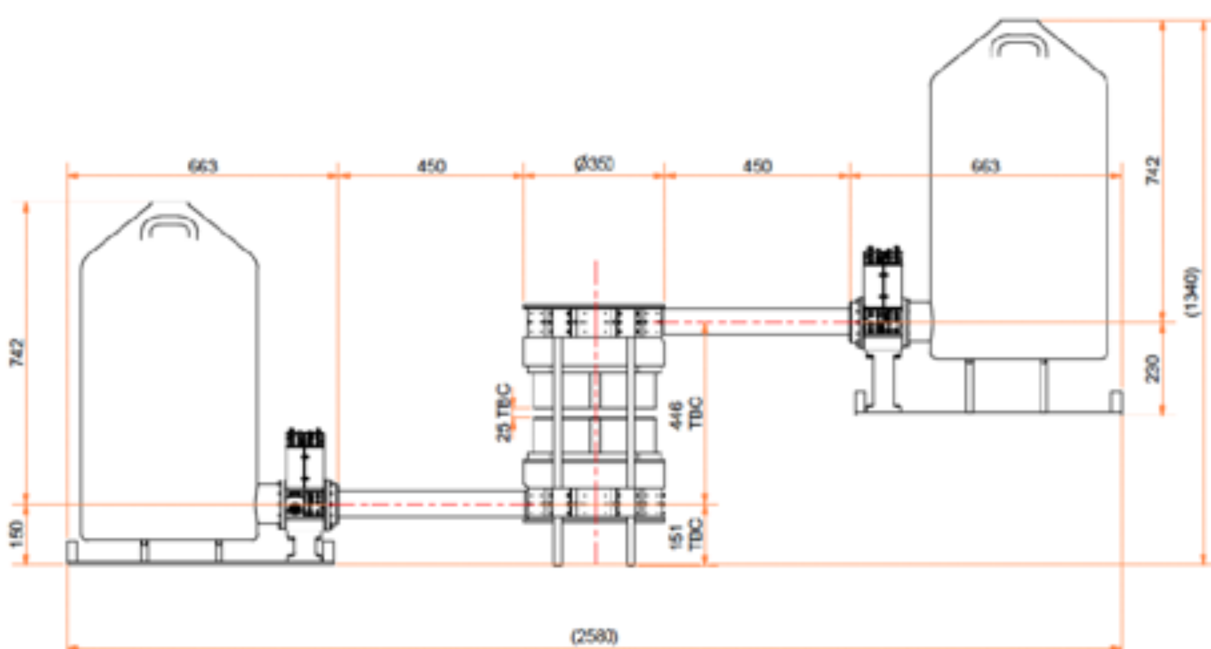
Rn free system

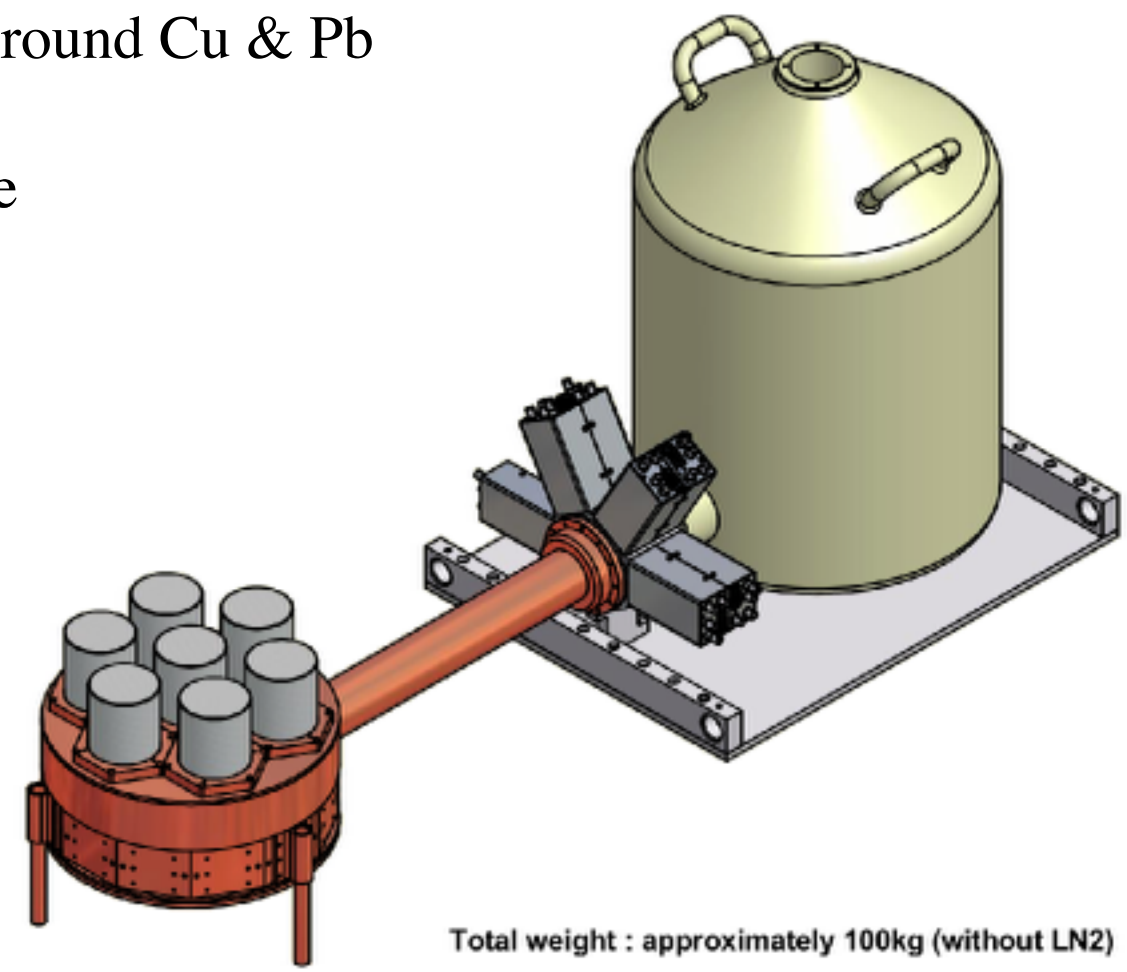
POSTER ID50
Kim GoWoon

ARRAY

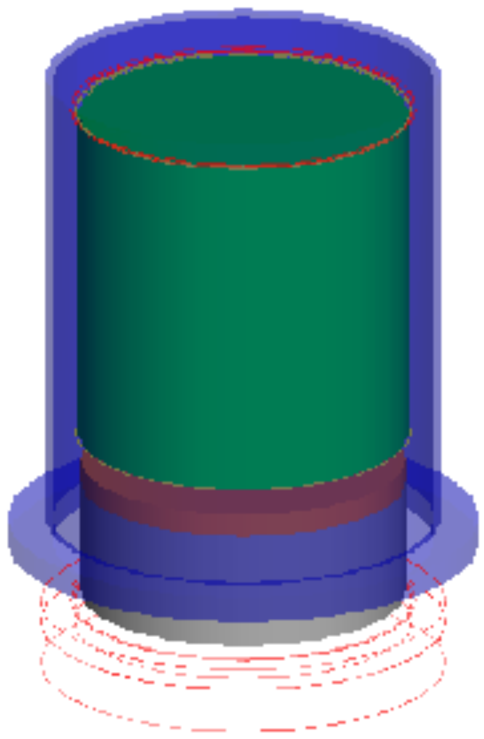
Developed in collaboration with CANBERRA,
the instrument is composed of
2 ARRAYS placed one above the other
with 7 HPGe (70% relative efficiency) each
total detectors: **14 HPGe**

STARTING CONFIGURATION
EndCap & Holder: Low background Aluminum
Inner shielding: low background Cu & Pb
O-ring Seal
Copper Plate





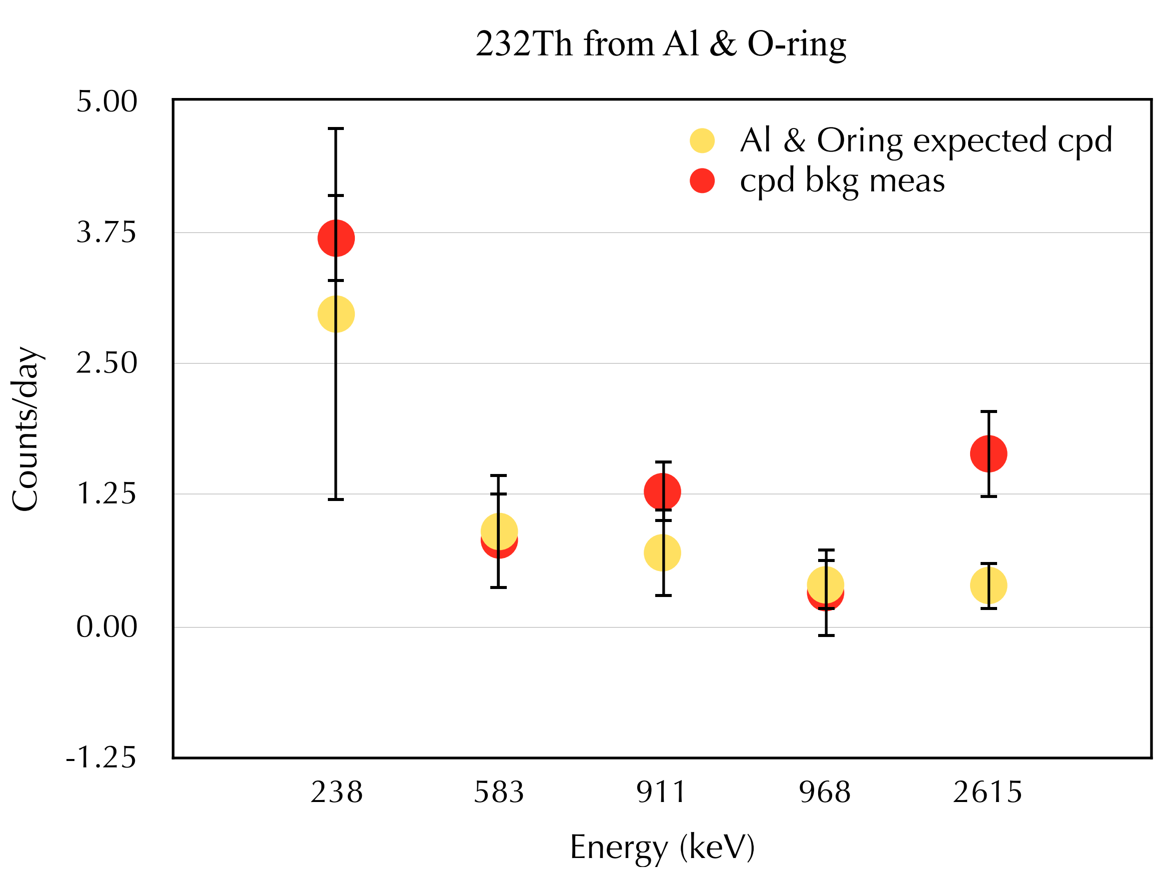
Intrinsic Background

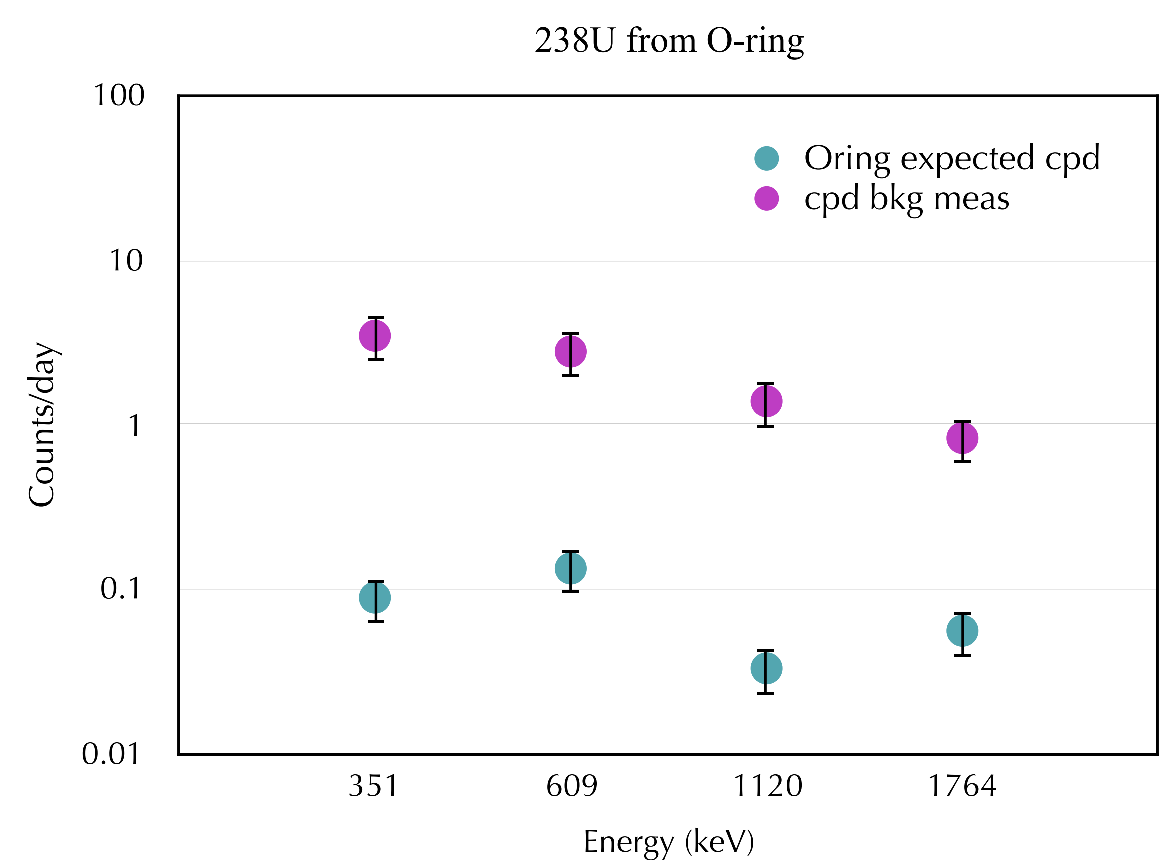


CANBERRA provided a SINGLE ELEMENT of the ARRAY
and samples of all the building materials

The samples have been measured with CANCOAX1 detector @Y2L
The activities used on Monte Carlo simulations
to evaluate the INTRINSIC BACKGROUND of the detector and its main sources

Considering only the detected activities (no limits) the main sources of radioactive background
Aluminum & O-rings
COMPARISON between the simulated expected cpd and the bkg cpd



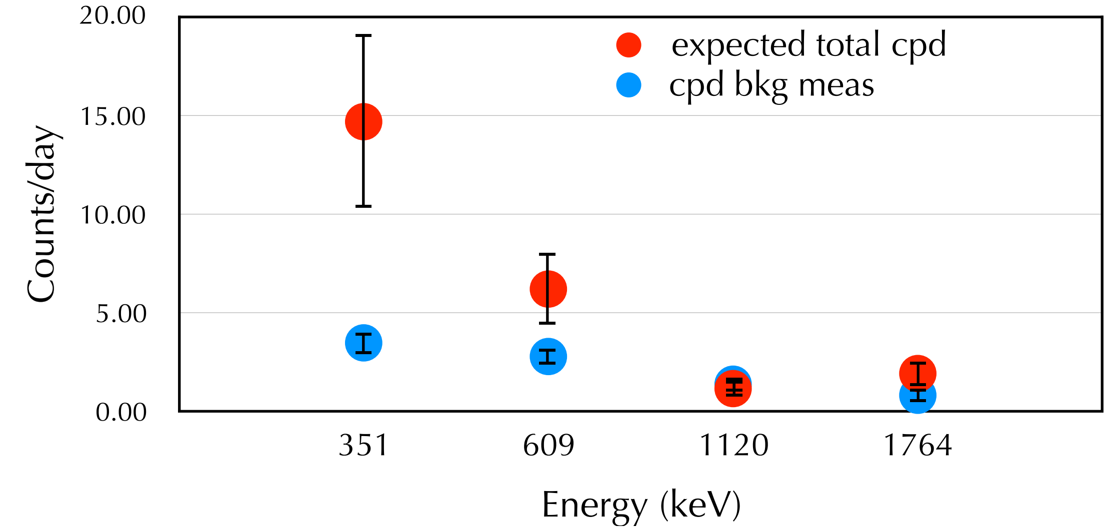


Sources of Background

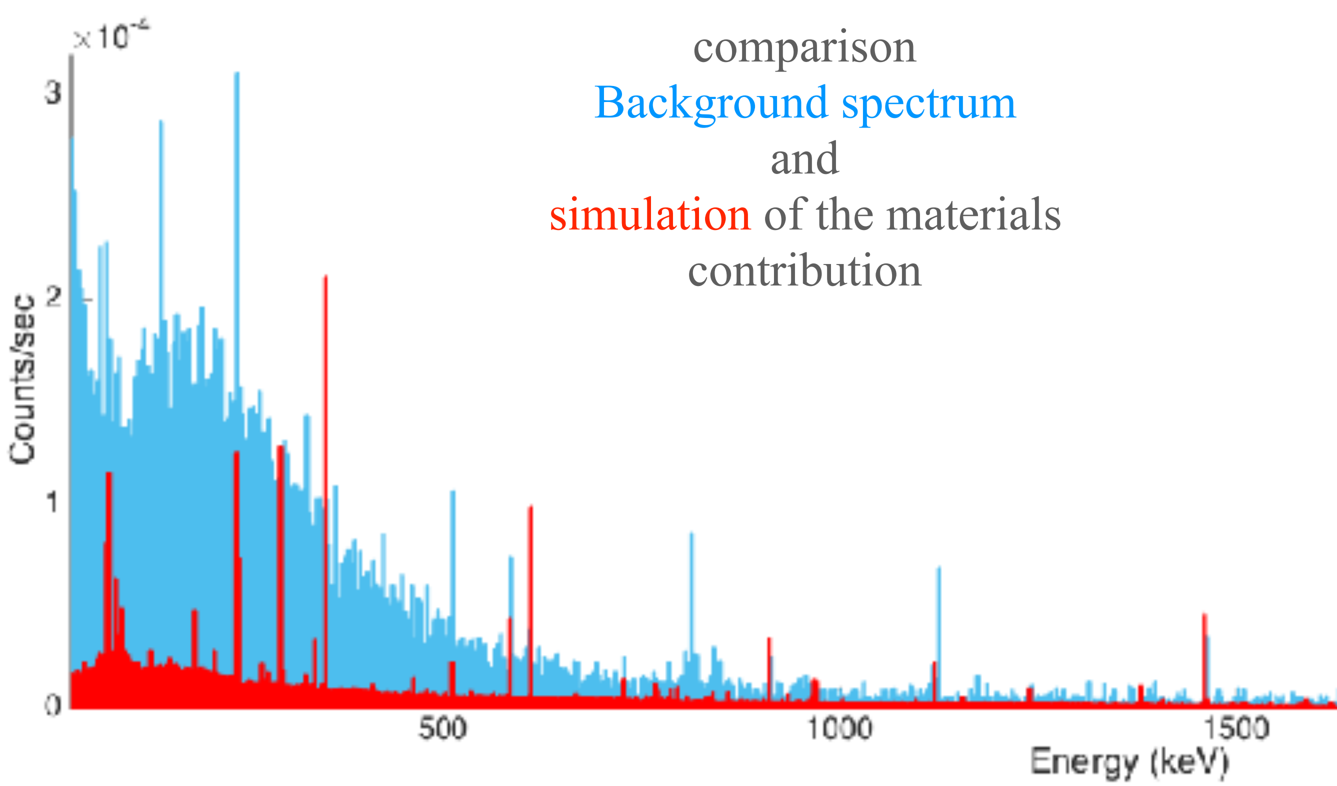
Analysis considering also the upper limits measured for ^{232}Th and ^{238}U
Contribution from every material

OVERESTIMATION OF THE INTRINSIC BACKGROUND

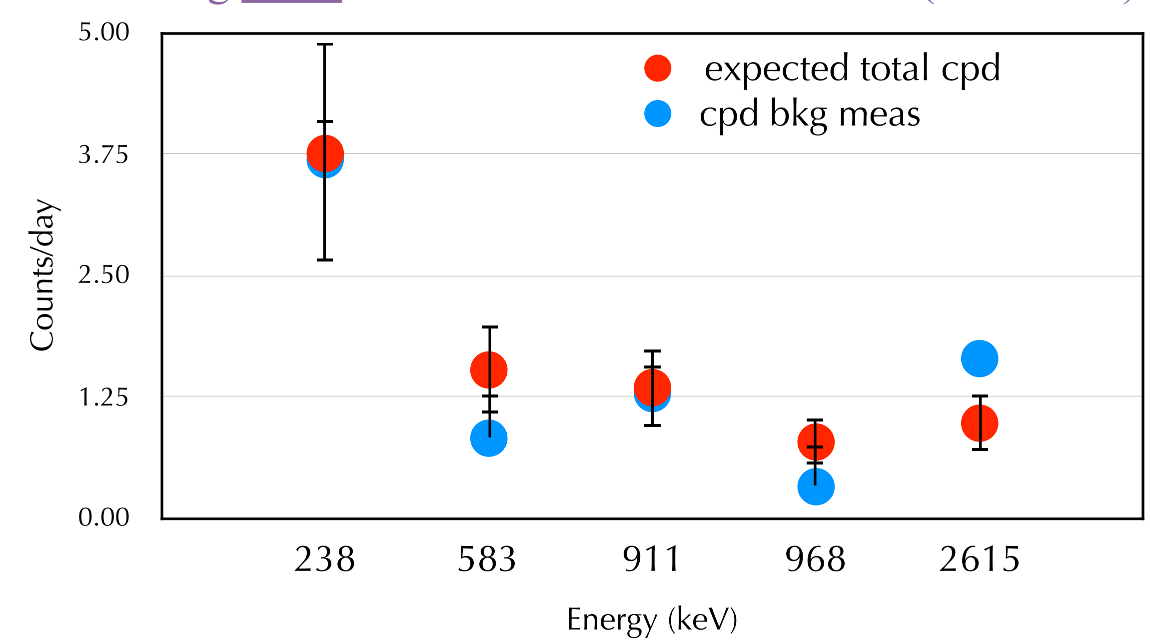
Considering ^{238}U contribution from all materials (also limits)



comparison
Background spectrum
and
simulation of the materials contribution



Considering ^{232}Th contribution from all materials (also limits)



The intrinsic background of ^{232}Th is due to the Aluminum and O-ring contamination

Final Configuration

The Ultra Low Background Facility

2 arrays of 7 HPGe detectors with 70% of relative efficiency
designed for **the detection of low contaminations**
the sensitivity can be improved thanks to coincidence measurements

Aluminum has been replaced by Copper everywhere
considering
the evaluation of the loss in efficiency at low energy
mechanical constraint

↓

End Cap & Holder surrounding the crystals are
made of COPPER
machined as thin as possible
for a total of 2 mm dead layer

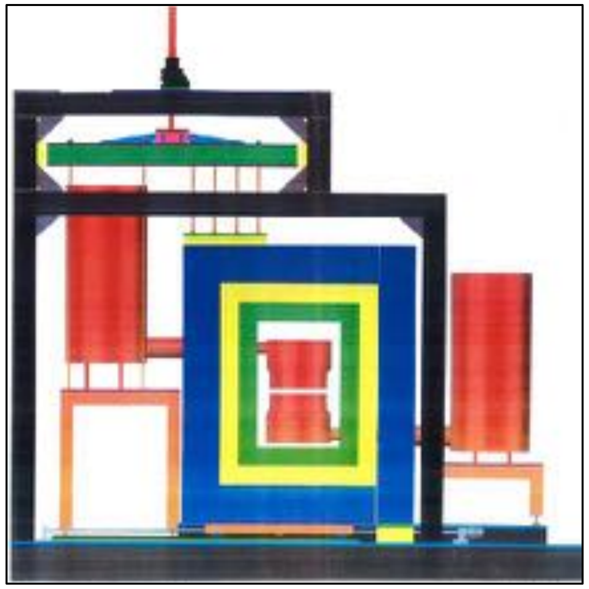
Accurate selection of O-rings
low contamination in Th and U:
16 ± 4 & 13 ± 4 mBq/kg respectively

Cryostat modification
indipendent vacuum on each canister

Shielding

Main Structure from outside: 20cm Lead + 10cm Goslar Lead + 10cm Copper

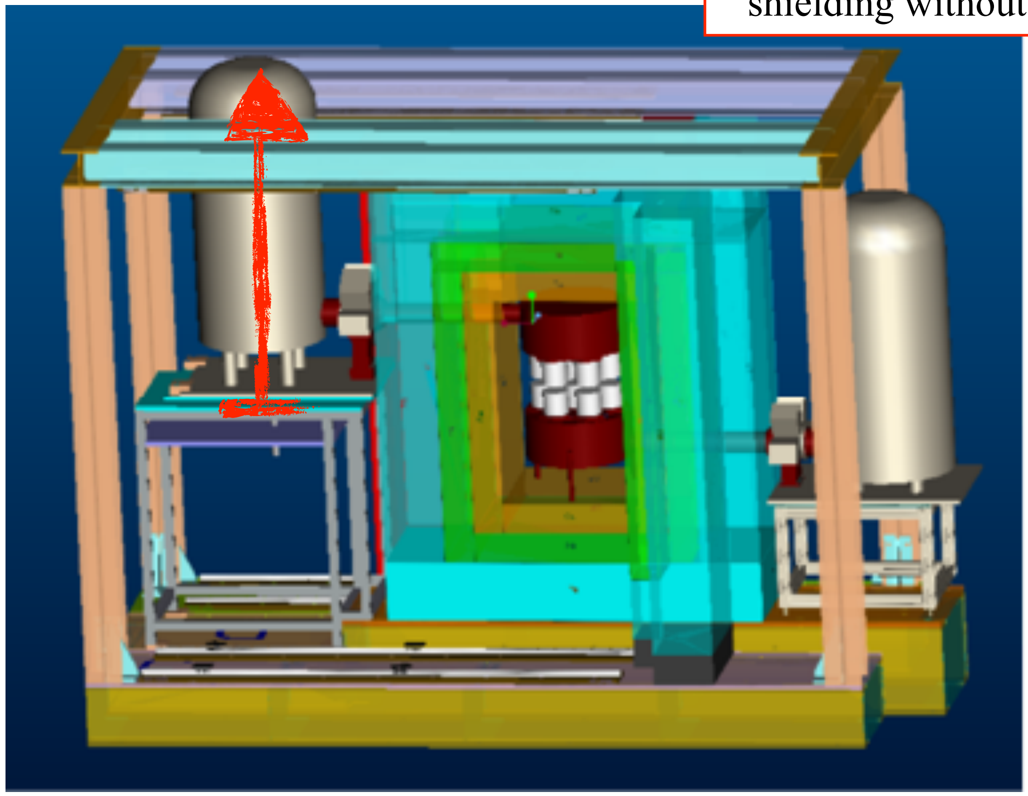
Two doors on the side can slide on rails using a motor system



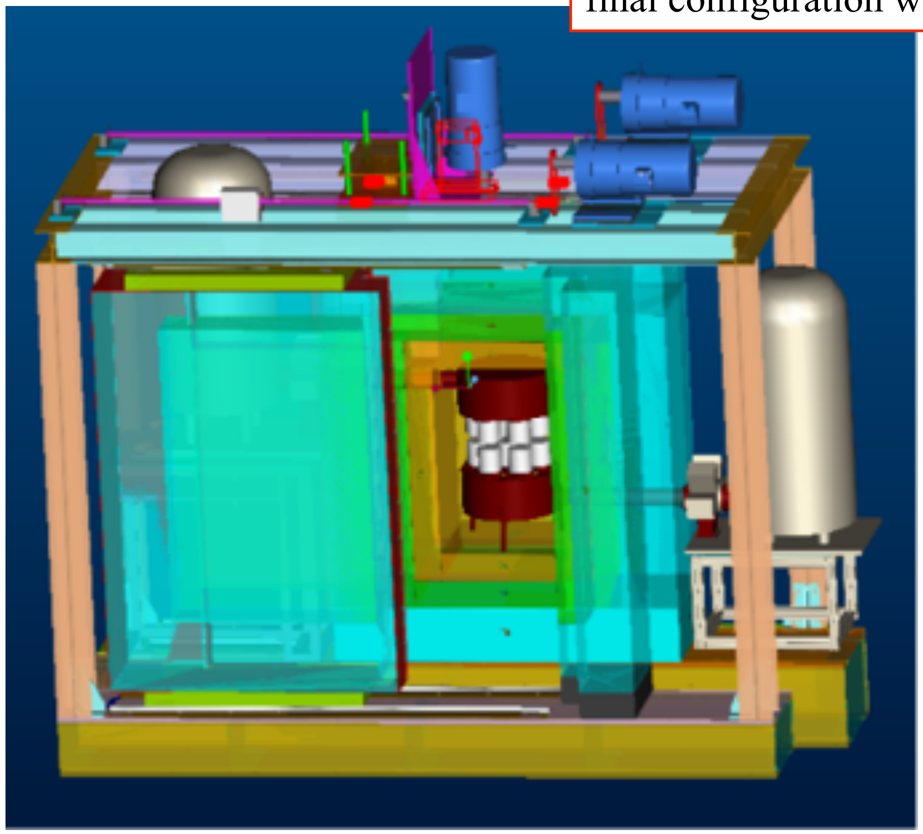
the top array should also lift to allow the placement of samples with different size. Specific tools are mandatory to lift the dewar and the array together.
A part of the shielding will also be lifted to prevent any damage on the cold finger

2 doors are needed because the instrument is very delicate

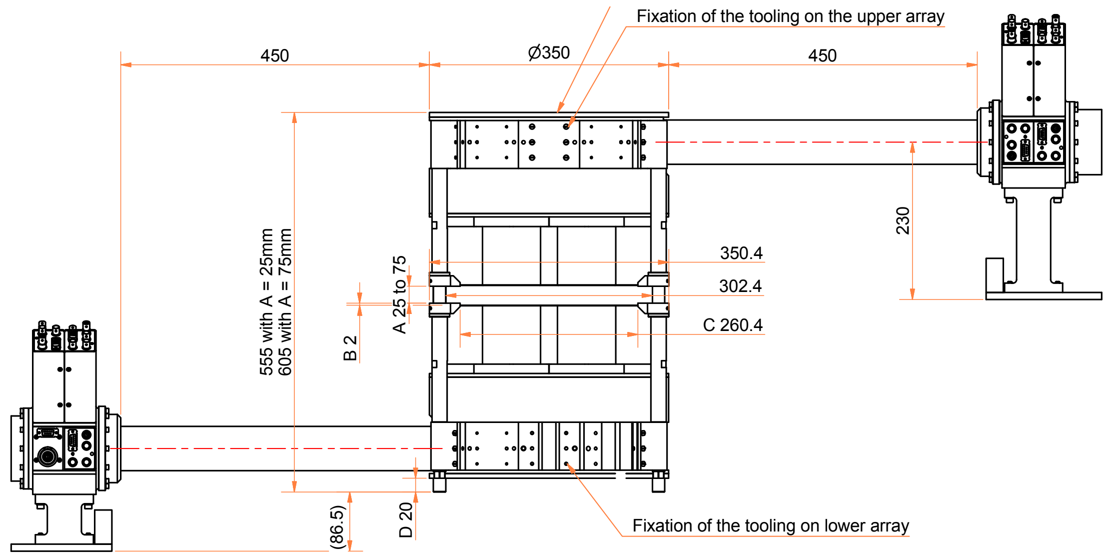
shielding without doors

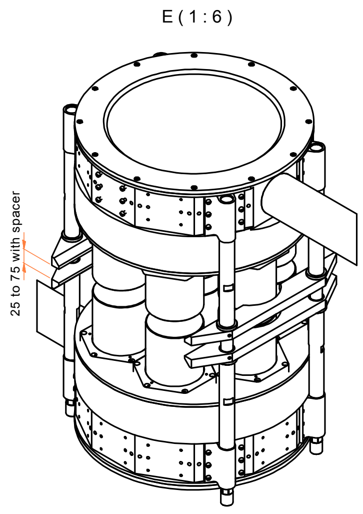


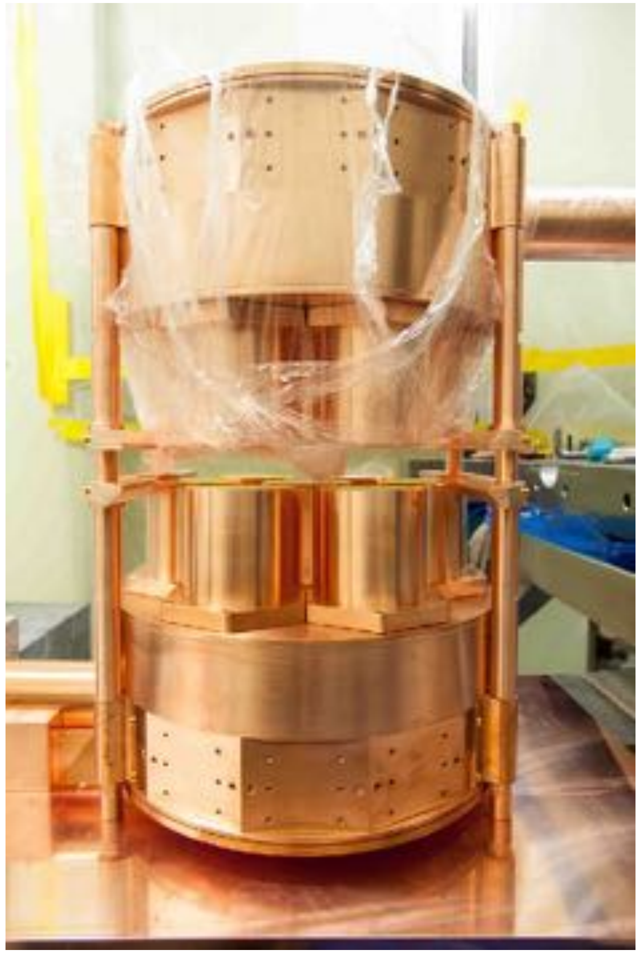
final configuration with the door open



Lifting







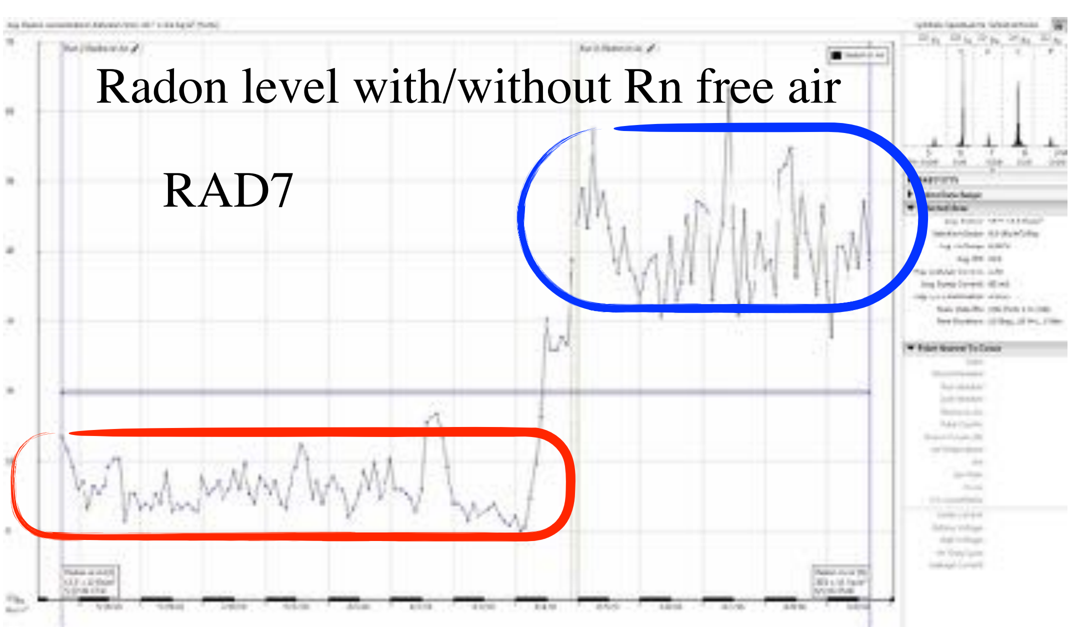
Lifting of 3 parts simultaneously
Top Array, Shielding, Dewar

Design of a Tool to lift the array
2mm each step (cold finger "safe" stress)

Adjustable spacers between the bars to fix the height
from 2.5 up to 5 cm

Support for samples

LAB



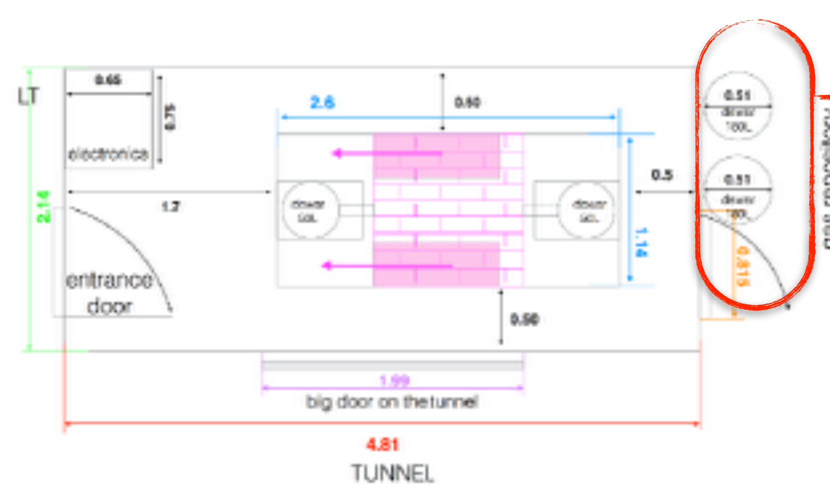
The available space in the Lab @ **A5**

The Array has an automatic refilling system

which connects the dewar to a LN2 tank

2 separated lines for the cooling

placed just outside the lab



Electronic Chain

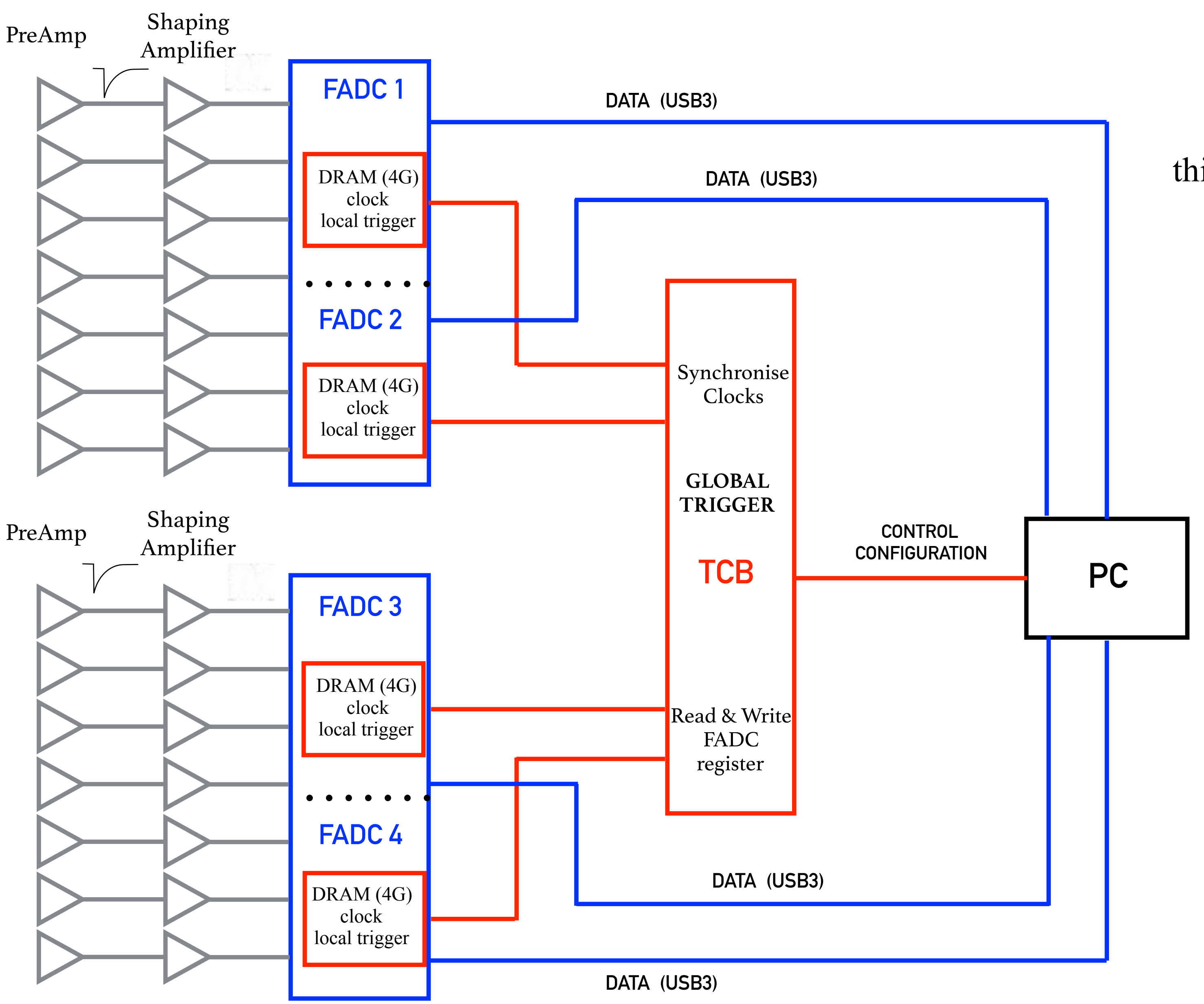
24V - 1.5A special NIM crate
no BNC BIAS SHUT DOWN

HV power supply iseg NHS6060
6 channels
positive
programmable

Shaping Amplifier CANBERRA 2026
shaping time 6μs

Flash Analog to Digital converter 500MS/s 12bit
2 modules with 4 channels each
dynamic range 2.5V

DAQ:
FADC 500 from NOTICE



local trigger signals are generated in the FADC
sent to the Trigger Control Board (TCB)
connected to all the modules
this will interpret this signal and generate a GLOBAL TRIGGER
which will be sent back to FADCs in 500ns
LAN cable connection

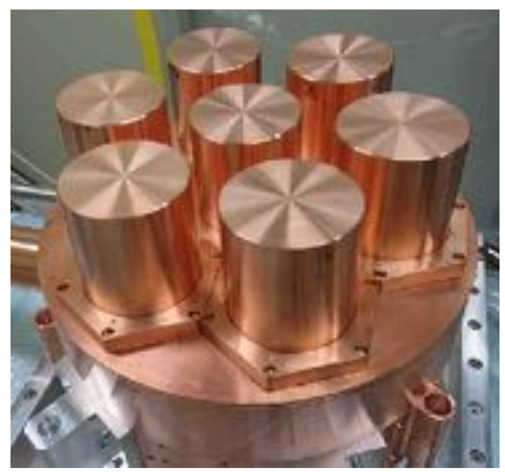
TCB
synchronise the FADCs clocks
and access to the FADCs register to send the information to PC

Energy Resolution

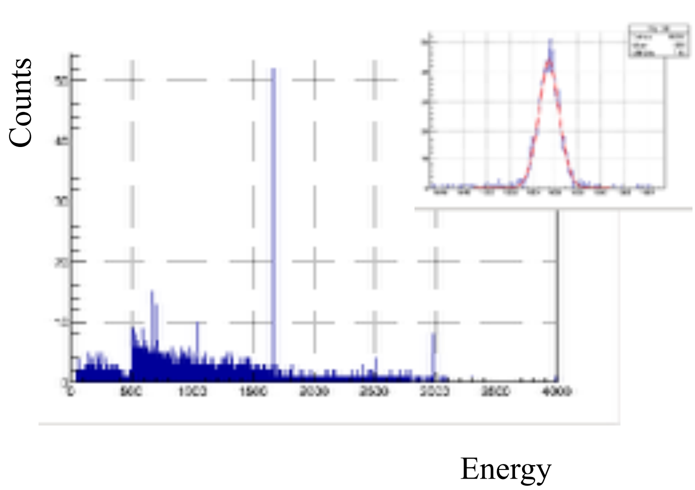
ENERGY RESOLUTION MEASUREMENTS

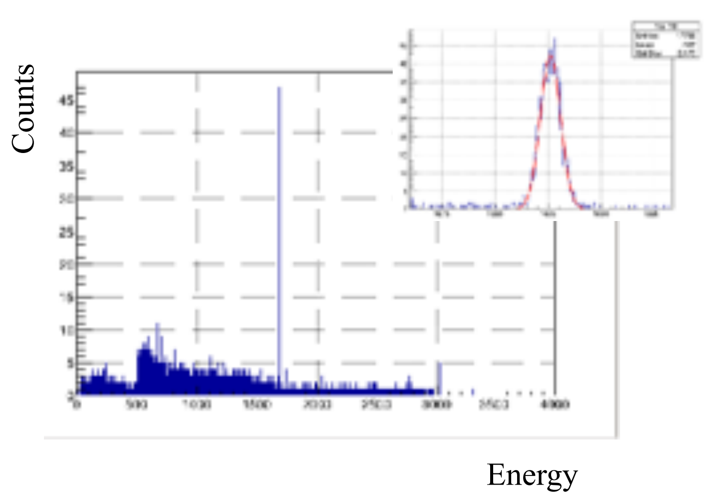
Energy Resolution (keV) for 1332.5 keV ^{60}Co						
DET0	DET1	DET2	DET3	DET4	DET5	DET6
1.97	1.76	1.78	1.89	1.75	1.73	1.79

Required energy resolution:
@ 1332 keV < 2.40 keV
@ 122 keV < 1.30 KeV



Energy Resolution (keV) for 122 keV ^{57}Co						
DET0	DET1	DET2	DET3	DET4	DET5	DET6
0.901	0.946	0.993	0.871	0.847	0.987	1.058



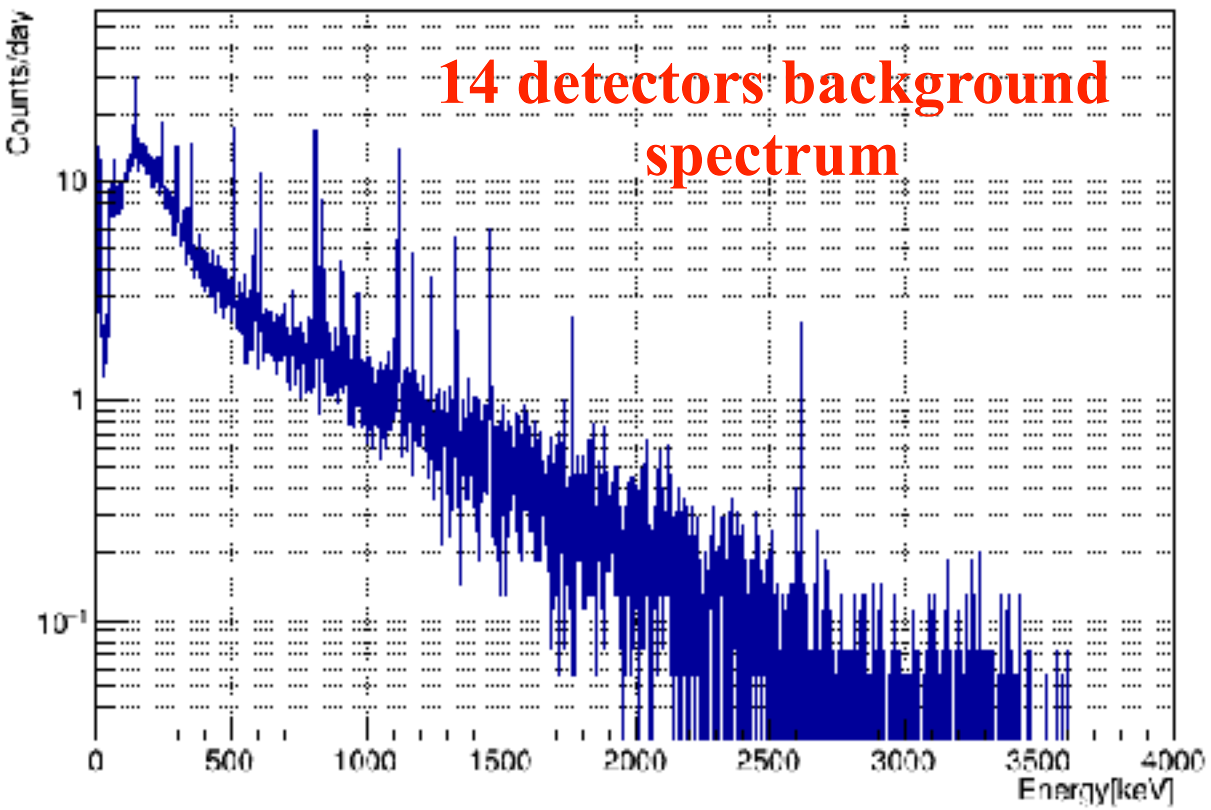


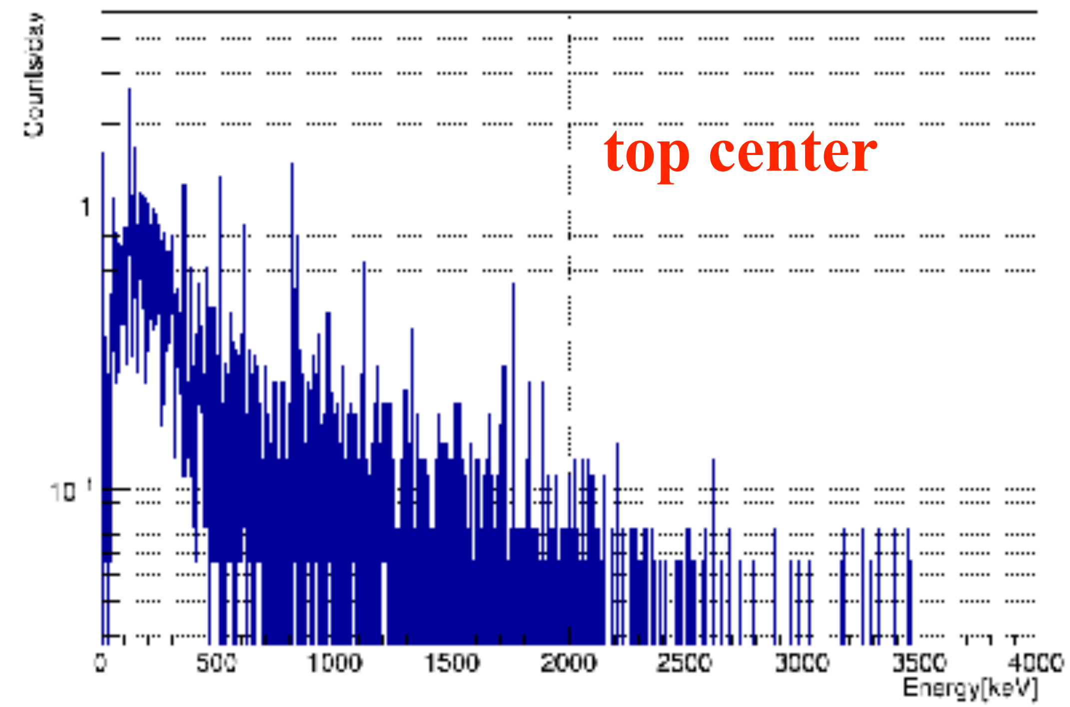
top Array

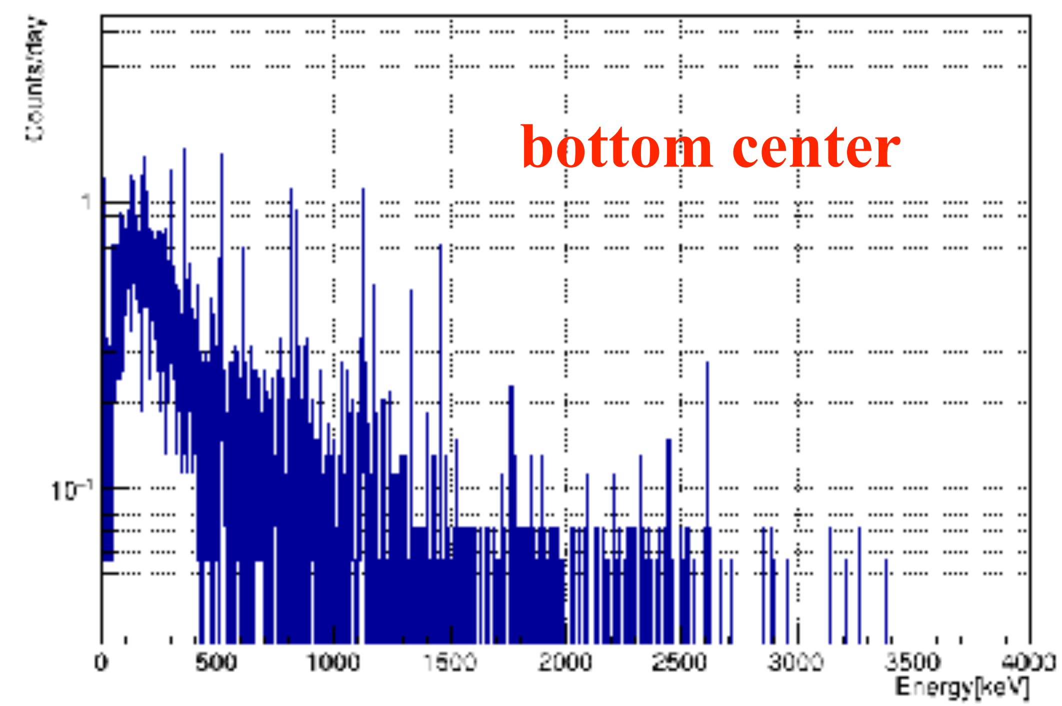
Energy Resolution (keV) for 1460 keV ^{40}K						
DET0	DET1	DET2	DET3	DET4	DET5	DET6
2.01	2.05	2.03	1.98	1.86	1.94	1.94

Background measurement

15.7 days measurement



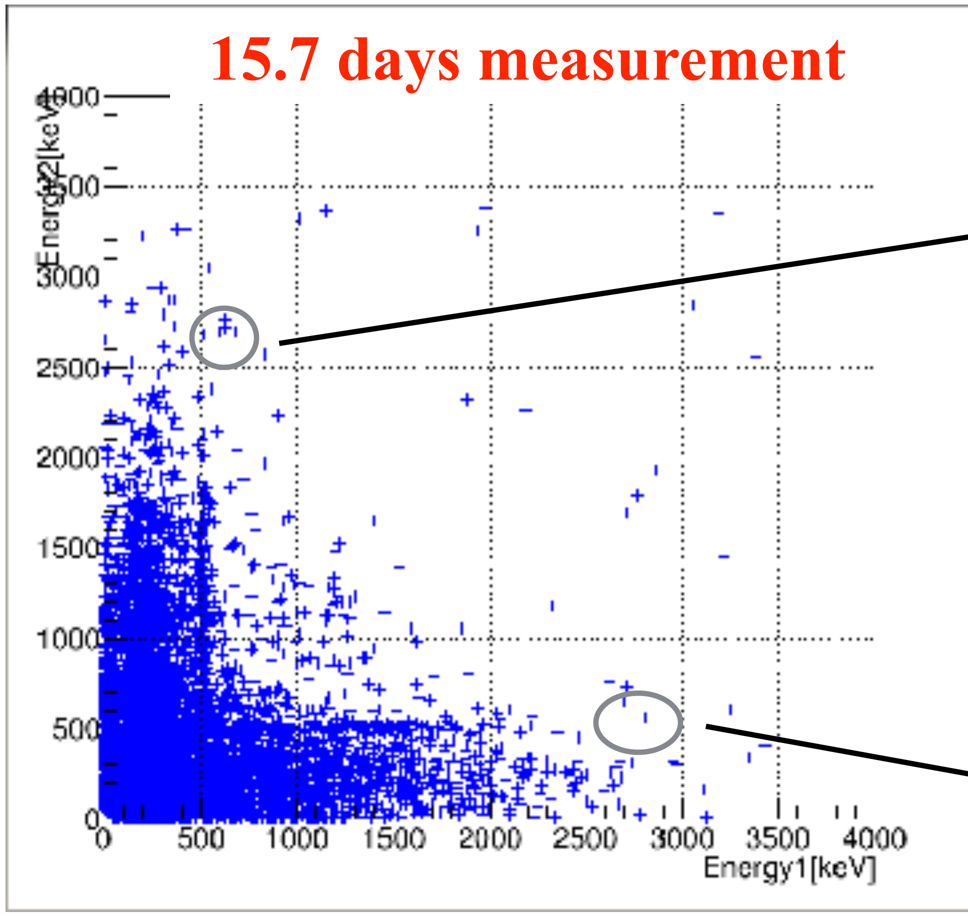




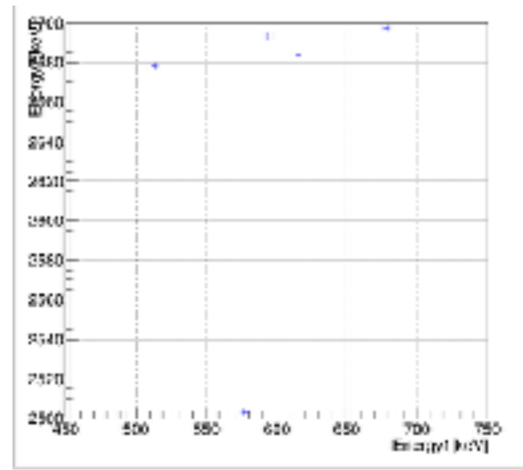
Isotope	Energy keV	cpd	err
^{214}Pb	352	24	2
^{214}Bi	609	21	2
^{228}Ac	911	11	2
^{208}Tl	2615	8	1
	583	10	2

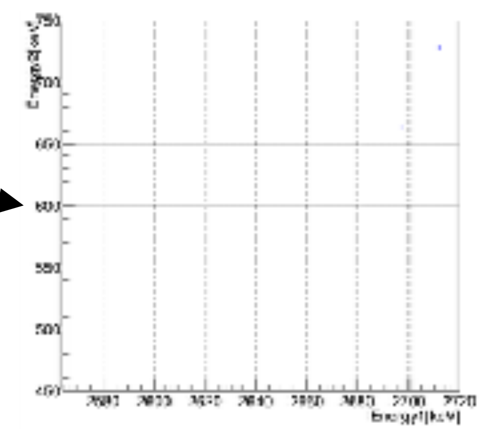
detector	Energy keV	rate
14 det	50-4000 keV	0.064
Top center	50-4000 keV	0.004
Bottom center	50-4000 keV	0.0035

Coincidence background

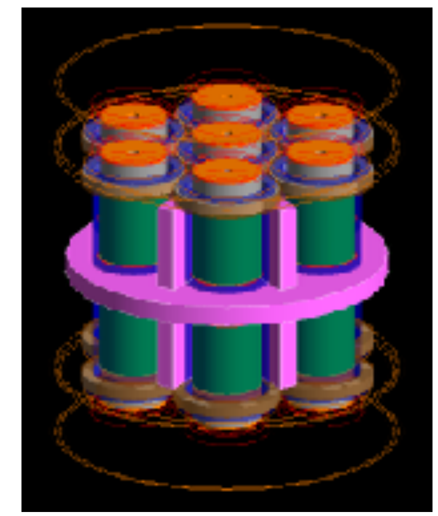


Coincidence analysis
Multiplicity 2
2 events in coincidence in 2 different detectors





Coincidence analysis on ^{208}Tl peaks:
2615 keV & 583keV



Simulation with **COPPER** sample surrounding all the detectors and a layer between the 2 arrays
TOTAL MASS ~ **36.5 kg**

COINCIDENCE on ^{208}Tl
2615 keV & 583 keV : 0 count
2615 keV & any (0~4000) keV : 1 count
583 keV & any(0~4000) keV : 43 counts

COINCIDENCE on ^{208}Tl
2615 keV & 583 keV

Coincidence Analysis **< 14 μBq/kg**
90% C.L.

Coincidence measurement & simulations

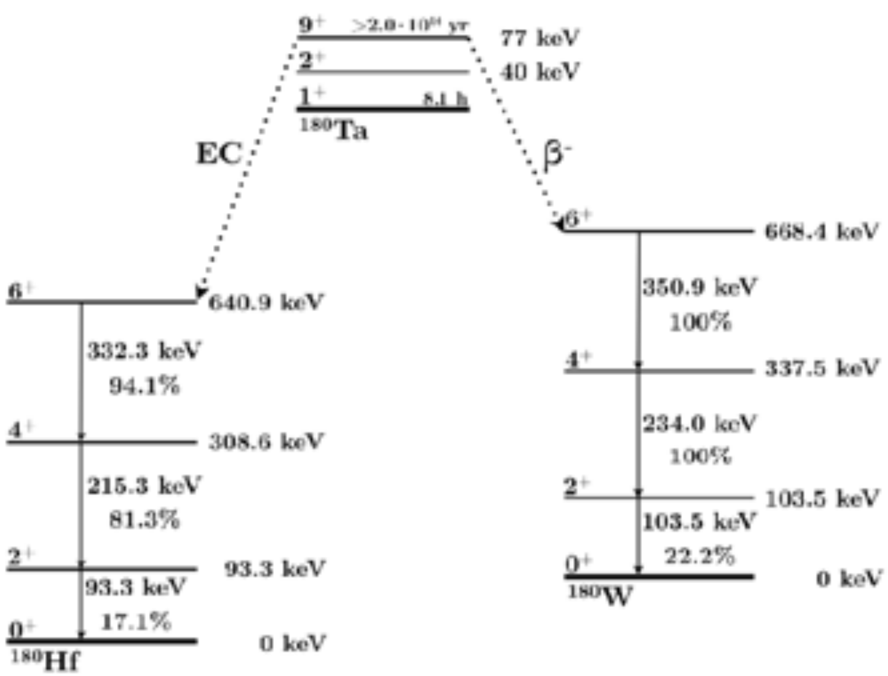
POSTER ID51
Kim GoWoon

Currently preparing our First RARE DECAY MEASUREMENT

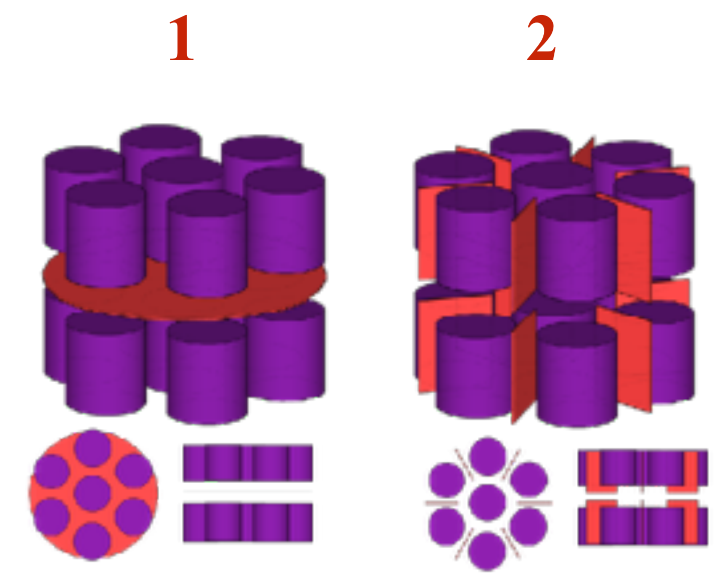
^{180m}Ta : $T_{1/2} > 4.5 \cdot 10^{16}$ yr (90 % C.I.)

*arXiv:1609.03725v1

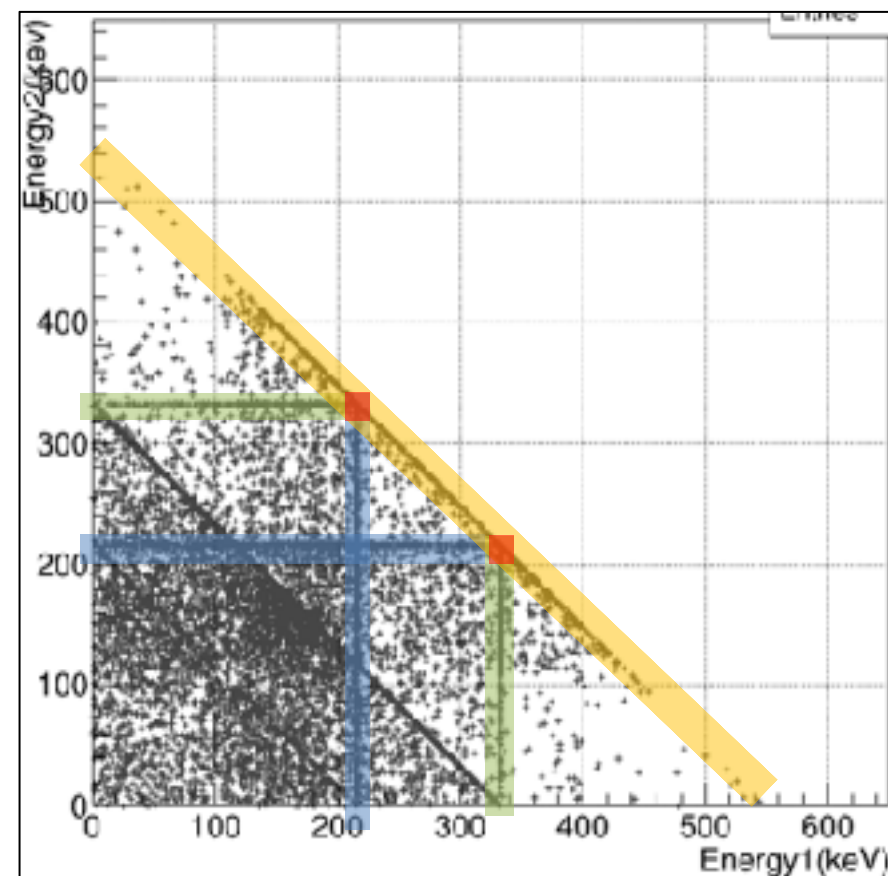
0.012% isotopic abundance
Long lived metastable state



EC & β^- decay
3 gammas in coincidence considered
332.3 keV & 215.3 keV (EC)
350.9 keV & 234.0 keV (β^-)
for simulations



Until now 0 events in the coincidence background
Expected counts/y in different configurations from 2 to 25



EC decay

Shape	Volume (cm3)	Mass (kg)	2MUL events	P1	P2	P3	P4
			Eff (%)	Eff (%)	Eff (%)	Eff (%)	Eff (%)
1	141.4	2.36	1.17	0.022	0.080	0.170	0.108
2	192.0	3.20	0.93	0.013	0.063	0.118	0.074
1+2	333.3	5.56	0.47	0.008	0.029	0.064	0.039

Other options are currently under study

MoO_3 powder measurement

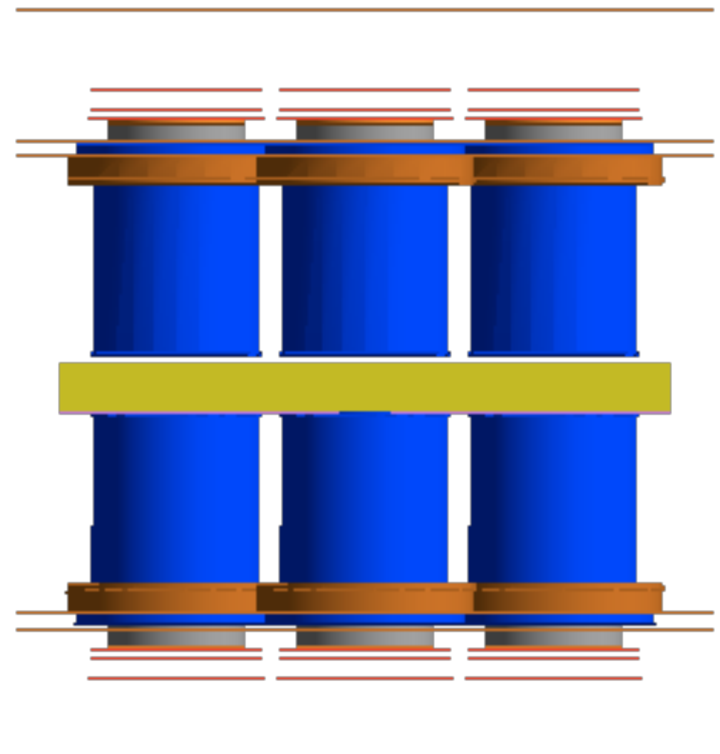
MoO_3 powder in ^{100}Mo for crystal growing of AMoRE experiment

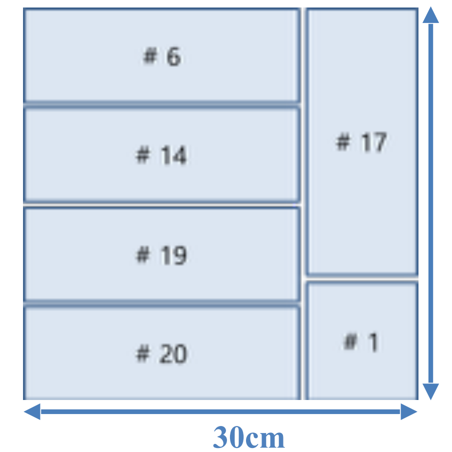
High sensitivity measurement of Uranium and Thorium contamination

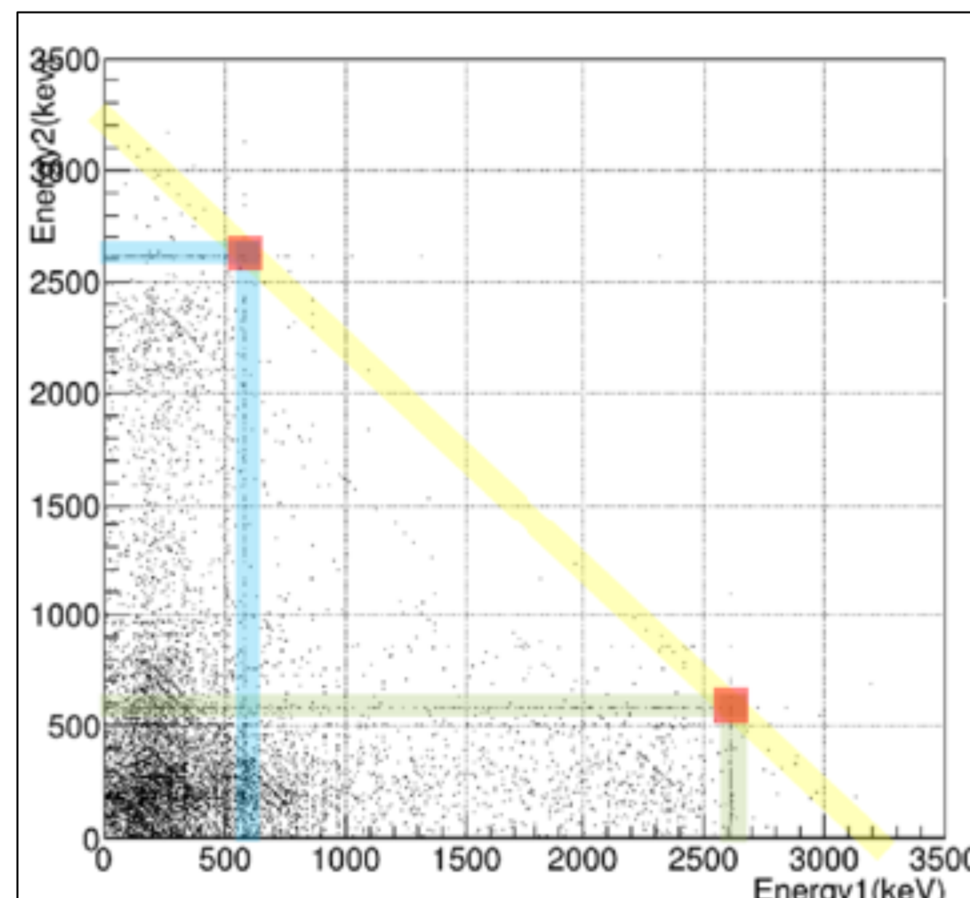
Isotopes		Peak (keV)	Efficiency (%)
^{232}Th	^{228}Ac	911	5.8
		968	5.5
	^{212}Pb	238	9.7
	^{212}Bi	727	6.8
	^{208}Tl	*2615*	2.0
		583	4.7
		860	4.7

For Thorium contamination coincidence 2615 keV & 583 keV from ^{208}Tl

case	Coincidence efficiency (%)
	w/ 1mm acrylic
P1	0.13
P2	0.14
P3	0.91
P4	1.90







Conclusion

The HPGe Array was developed in collaboration with CANBERRA
The final configuration consist in 2 separated cryostats with 7 HPGe detectors each
The two parts are facing each other
To reach the lowest possible background
Aluminum was replaced with Copper
Orings were carefully selected
A dedicated shielding was designed and constructed in Y2L

The Array is currently taking data
Background measurement
The first scheduled measurement is MoO_3 enriched powder for the crystals of the AMoRE experiment
The expected sensitivity of the ARRAY will allow
rare decays searches
The optimisation of the ^{180m}Ta measurement is ongoing